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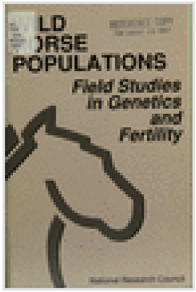

Wild Horse Populations: Field Studies in Genetics and Fertility : Report to the Bureau of Land Management, U.S. Department of the Interior (1991)

Pages
52
Size
5 x 9
ISBN
0309291623

Committee on Wild Horse and Burro Research; Board on Agriculture; National Research Council

WILD HORSE POPULATIONS:
FIELD STUDIES IN GENETICS AND FERTILITY

Report to the
Bureau of Land Management
U.S. Department of the Interior

Committee on Wild Horse and Burro Research
Board on Agriculture
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C. 1991

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This project was supported by the Bureau of Land Management, U.S. Department of the Interior, under contract no. AA852-CT5-11.

Available from:

Board on Agriculture
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America

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Preface

When Congress passed the Wild Free-Roaming Horse and Burro Act (P.L. 92-195) in 1971, it decreed that the secretaries of interior and agriculture are to engage in the "protection, management, and control of wild free-roaming horses and burros on public lands . . . [thenceforth] to be considered . . . as an integral part of the natural system" on those lands (U.S. Congress, 1971). The public lands referred to are those under the administration of the Bureau of Land Management (BLM) and the Forest Service. Most horses and burros are on land administered by BLM, and most of the management responsibility rests with this agency.

To casual travelers through the arid and semiarid lands of the western United States, there may seem to be little human land use and ample room for these equine "living symbols of the historic and pioneering spirit of the West." But in fact diverse interest groups demand an array of competing, often conflicting, uses of these lands: mining, timber harvesting, domestic livestock grazing, consumptive and nonconsumptive wildlife uses, recreation, water harvest, and energy production.

Grazing by wild horses and burros is one of these competing uses, and it arouses the animosity of interest groups that feel encroached upon. In particular, livestock groups consider that horses and burros compete with domestic animals for range forage; traditional wildlife advocates have the same concerns for indigenous wildlife; and other environmental groups consider equines to be aliens in ecosystems that have not evolved with, and are damaged by, them. On the other side there are equally strong advocates for wild horses and burros who consider these animals to be part of the western heritage and the aesthetic atmosphere of the region.

Under existing law, it is the responsibility of the BLM and Forest Service to mediate these conflicting demands and to negotiate aggregate uses of the public lands among the interest groups. In areas with wild horses and burros, the compromises include decisions on the number of these animals that should be maintained along with the prescribed number of livestock and indigenous wildlife.

All interest groups agree on one goal: the population of wild horses and burros, in conjunction with other wild and domestic grazing animals, should not be allowed to rise to levels at which the animals degrade the ecological health of rangelands. Hence, there is agreement that the aggregate numbers of wild horses and burros, livestock, and indigenous wildlife, and the specific number decided upon for each class, should be controlled within the carrying capacity of each area. The BLM has adopted a policy stating that the management level—their judgment of the appropriate numbers—for wild horses on the public lands of the western United States should be 31,000. As of early 1990, this limit had not been reached; populations during the 1980s generally numbered between 40,000 and 50,000.

Through yearly reproduction and a relative scarcity of natural population limiting factors in areas with healthy vegetation, wild horse and burro populations increase at annual rates reportedly varying between 6 and 20 percent. Rates in the higher part of this range are more likely at low population densities and in areas where the range vegetation is in good to excellent condition. Thus, western populations of horses and burros increase several thousand each year.

Given the unremitting tendency of these animals to increase, and decisions to hold horses and burros in each area at agreed-upon numbers, the management agencies face a continuing need to control population. P.L. 92-195 (U.S. Congress, 1971) states

> The Secretary may order wild free-roaming horses and burros to be destroyed in the most humane manner possible when he deems such action to be . . . necessary to preserve and maintain the habitat in a suitable condition for continued use . . . or such action is the only practical way to remove excess animals from the area.

But the agencies have rejected mass euthanasia as a socially unacceptable solution and instead have developed the Adopt-a-Horse and Adopt-a-Burro programs. Periodic roundups of animals make those numbers in excess of management levels available for the general public to adopt as pets and work animals.

The adoption program has been generally successful, placing 81,000 animals across the United States from 1972 through 1987 (U.S. Department of the Interior, 1989). However, it requires substantial funds, involving extensive helicopter time for roundups, high-quality pen facilities and feed to hold the animals until adoption, veterinary fees, and transportation costs to move large numbers of animals across the country to adoption centers. It also places heavy demands on understaffed agencies that have numerous other natural resource management responsibilities across half the area of the western United States. Moreover, when the adoption demand is saturated, the agencies are faced with large and growing numbers of animals that need feed and shelter. This occurred during the mid-1980s when, after unusually large roundups, the BLM maintained several thousand wild horses in pens at Lovelock, Nevada, at an annual cost of several million dollars. In recent years, the BLM budget for wild horse and burro management has ranged between $10 million and $20 million annually.

One alternative herd-control approach to roundup and adoption is reproductive suppression. In 1979, the National Research Council's Committee on Wild and Free-Roaming Horses and Burros was established under mandate of the Public Rangelands Improvement Act (P.L. 95-514) in part to design a wild horse and burro research program and to evaluate research funded by BLM (U.S. Congress, 1978). In 1980 this committee recommended an extensive research program that included studies on reproductive inhibition in mares. Five research projects were initiated in 1980, although none addressed fertility control. In 1982, the committee filed a final report (National Research Council, 1982). In 1983, all of the projects were terminated.

In part because of growing concern with the cost of holding increasing numbers of unadopted horses in the Lovelock corrals, Congress appropriated $1 million in fiscal year 1985 for further research. The report accompanying the appropriations bill for the fiscal year 1985 budget of the U.S. Department of Interior stated (Robert F. Burford, U.S. Department of the Interior, personal communication, November 20, 1984)

> [T]here is still significant disagreement over how many animals are excess, what historic levels were, and what is the current level of reproduction. . . . [Thus we direct] the Bureau, through the National Academy of Sciences, to continue to develop data to answer these and other relevant questions.

The Committee on Wild Horse and Burro Research was constituted in 1985 at the request of BLM and asked once again to consider research needs. BLM officials suggested a need for research on fertility control and computer simulation of alternative population control strategies. Upon committee recommendation, two projects were ultimately initiated and funded by BLM in 1985—one on fertility control and a related one on population genetics.

The committee's final report summarizes its review of the research results. The genetics study has been completed. The fertility control project has one more field season remaining as this report is written, but the data so far accrued have been extensively analyzed and modeled. When the modeling and remaining research have been completed in the fall of 1990, the fertility control project will provide not only a technical evaluation of the fertility control methodology used, but also an assessment of its population control efficiency and cost. BLM should then be in a position to compare the new methods with existing ones and to make policy decisions.

Frederic H. Wagner, *Chair*
Committee on Wild Horse and
Burro Research

1

Introduction

The Committee on Wild Horse and Burro Research was established in 1985 at the request of the Bureau of Land Management (BLM). Its charge was to

- Review research on wild horses and burros completed since 1982;
- Assess the research recommendations of an earlier committee of the National Research Council in light of current issues, and update these recommendations if necessary;
- Develop guidelines to assist the BLM in contracting for additional research studies;
- Monitor the progress of contracted research projects; and
- Evaluate the final reports of the research projects and prepare a final committee report.

Under this arrangement, the BLM expressed its views on the priorities for research to be conducted. The committee then presented its research recommendations and guidelines. Three areas of research were chosen by the BLM: wild horse population genetics, control of fertility in wild horses, and simulation modeling of alternative population-control strategies. The areas chosen for research focused exclusively on wild horses. Wild burros were not studied in any of the research reviewed by this committee.

In 1985, requests for proposals (RFPs) were issued by the BLM. The committee carried out a scientific review of the responses to the RFPs. Subsequently, the BLM awarded a grant to the University of California at Davis for a genetics research project and to the University of Minnesota for a fertility control project. The modeling research was not funded because of data limitations.

This report reviews the design and results of BLM-funded research on wild horse genetics and on fertility control. It is based on meetings with the research groups from the University of California at Davis and the University of Minnesota over a 4-year period as well as numerous other communications. The report also addresses concerns expressed by some individuals and interest groups that injuries to and deaths of horses during the conduct of these research projects have compromised the integrity and usefulness of the research results.

2

Research and Results

The Bureau of Land Management (BLM) awarded research grants in 1985 for the study of wild horse genetics and fertility control. The University of California at Davis conducted its 3-year study on wild horse population genetics and submitted a final report to BLM on January 15, 1988 (Bowling and Touchberry, 1988). The University of Minnesota began its study of wild horse fertility control on October 1, 1985, and will complete it in the fall of 1990. Although the results from one remaining field season in the fertility study are not included in this report, the data gathered to date have been extensively analyzed and permit the conclusions presented in Chapter 5.

GENETICS STUDIES

Research on wild horse parentage and population genetics included a genetic analysis of the inheritance of different proteins present in red blood cells and serum. From December 1985 through October 1986 researchers from the University of California at Davis collected blood samples from nearly 1,000 horses at seven trap sites in the Great Basin area of Oregon and Nevada. The genetics studies on the free-ranging feral horses had the following four objectives:

1. Assess average and individual heterozygosity in the populations to determine if there has been loss of heterozygosity or inbreeding through genetic drift, selection, removals, or management restrictions on animal movement;
2. Estimate the contributions of the original wild mustangs (descendants of animals released by the Spanish) and the current domestic lineages (13 breeds) to the present feral horse populations;

3. Evaluate the several populations for possible divergence in gene frequencies and for the development of population substructure; and
4. Determine parentage and particularly paternity within bands to evaluate the proportion of foals sired by the dominant band stallion.

An important feature of horse social organization and behavior is year-round bands. Bands generally consist of females, their young, and a single stallion. Bands with more than one male do exist, but are generally short lived, lasting from several hours to several months. Bachelor males also form bands, although older horses, more than 14 years old, spend significantly more time alone than younger males, particularly those 2 to 5 years of age. Bands can contain from one to eight (rarely more) females, with an average of between three and four mares per band. Females, however, do not band together for life, and will stray from one band to another. Interestingly, Berger, in his 5-year study of wild horses, reports never seeing a mare driven from a band by a stallion (Berger, 1986).

Methods Used

The assays used included red cell antigens (50 alloantigens at 7 loci), isoenzyme (red cell and serum isozymes), and serum protein electrophoresis (76 alleles at 12 loci) for a total of 19 polymorphic loci. Loci known to be polymorphic in domestic horses were chosen for analysis. Selection was based on the objective of measuring the occurrence and frequencies of alleles for a comparison with the data available on many domestic horse lineages. This approach does not evaluate polymorphisms or rare alleles at other loci. It detects new alleles at the studied loci. Observations on coat color and pattern variants at seven loci were also collected.

Blood samples were collected from 975 horses in five populations. Two sites had two trap locations each, providing paired subpopulations; the other three sites had one trap site each (Flanigan, 175 animals in 30 bands; Wassuks, 119 in 21 bands; Beaty Butte, 112 in 17 bands; Stone Cabin, 239 in 30 bands at site 1 and 127 at site 2; and Clan Alpine, 104 in 17 bands at site 1 and 99 in 12 bands at site 2). Separation of the locations by distance and geography makes it unlikely that genetic exchange occurred between these populations. The band compositions and paternity assignments may have been compromised in two cases: (1) a roundup and removal of some horses was conducted by BLM at the Flanigan study area in September 1985 prior to the sample collection in December; and (2) samples were collected at the Beaty Butte area in February 1986 after a BLM reduction roundup in November 1984. Data on the domestic breeds were drawn from blood samples from a breed registry laboratory; they ranged from 79 to 14,517 samples per breed. Thirteen domestic breeds are thought to be associated with the horses of the Great Basin (Figure 2-1). They include the Arabian, Criollo, and Mangalarga breeds.

FIGURE 2-1 The Great Basin of the western United States.

Results

Data were analyzed by calculating allele frequencies at individual loci, proportion of heterozygous loci in individuals and in populations, Nei's genetic distance, and dendrograms. Parentage was accepted on the basis of congruent allelic specificity at each locus for foal and dam pairs and with the band stallions. The numeric results are summarized in Tables 2-1, 2-2, and 2-3, and in Figure 2-2. They indicate the following:

- There were no significant deviations from Hardy-Weinberg equilibrium proportions indicating that the horses sampled at each site were members of an interbreeding population within the limits of the 19 loci examined.
- The horses from the paired sites within the Stone Cabin and Clan Alpine sites could each have been members of a single randomly mating population.
- The number of effective alleles for wild horses averaged 41.3 ± 2.8 (range 38.8 to 46.3) and for domestic breeds averaged 40.3 ± 4.0 (range 33.7 to 46.8).
- The average heterozygosity was 0.402 ± 0.009 and 0.353 ± 0.011 for wild and domestic horses, respectively.
- The differences between populations of Great Basin horses were less than between breeds of domestic horses, based upon Nei's population measures.
- Unique variants in the wild horses were observed only at the highly polymorphic Pi locus.
- The above data and the dendrograms support the hypothesis that Great Basin horses originated from escaped or released domestic draft, saddle, and cavalry animals.
- Paternity assignments included 121 foals from 69 intact harem bands. The data indicate that about one-third of the foals were not sired by the harem stallions. This exclusion rate did not change when the data from the sites disturbed by roundups were excluded.

TABLE 2-1 Allelic Variation in Horses at 19 Blood Type Loci

Trap Site or Domestic Breed	Number of Alleles			Number of Effective Alleles	Average Heterozygosity (Standard Error)
	Blood Group	Protein	Total		
Trap site, wild and free-roaming horses					
Flanigan	30	41	71	38.3	0.378 (±0.058)
Wassuks	24	33	57	38.8	0.380 (±0.062)
Beaty Butte	25	36	61	39.7	0.442 (±0.045)
Stone Cabin 1	30	48	78	46.3	0.423 (±0.062)
Stone Cabin 2	28	38	66	43.0	0.416 (±0.059)
Clan Alpine 1	31	51	82	42.5	0.404 (±0.058)
Clan Alpine 2	28	45	73	40.5	0.368 (±0.061)
Domestic breed					
Arabian	29	37	68	37.1	0.346 (±0.062)
Thoroughbred	24	34	58	33.7	0.295 (±0.060)
Quarter horse	36	50	86	45.0	0.403 (±0.062)
Standardbred	29	40	69	39.1	0.413 (±0.048)
Morgan horse	34	51	85	42.9	0.410 (±0.056)
American saddlebred	34	47	81	40.7	0.386 (±0.059)
Tennessee walking horse	29	42	71	35.8	0.350 (±0.056)
Belgian	31	42	73	46.8	0.443 (±0.059)
Shire horse	28	43	71	38.3	0.381 (±0.058)
Argentine Criollo	29	46	75	41.1	0.410 (±0.061)
Chilean Criollo	30	44	74	41.8	0.428 (±0.052)
Mangalarga	26	38	64	36.8	0.305 (±0.068)
Mangalarga marchador	30	48	78	45.4	0.412 (±0.066)

SOURCE: Bowling, A. T., and R. W. Touchberry. 1988. Wild horse parentage and population genetics. Final research report to the U.S. Department of Interior, Bureau of Land Management, January 15. University of California at Davis. Photocopy.

TABLE 2-2 Nei's Population Measures for Horses

	Population Cluster[a]		
	Wild	Domestic	Total
Heterozygosity			
Total	0.429	0.443	0.441
Subpopulation	0.402	0.383	0.389
Diversity			
Interpopulational	0.027	0.060	0.052
Subpopulations relative to total population	0.063	0.136	0.117

[a]Population number is 7 wild and 13 domestic horses.

SOURCE: Bowling, A. T., and R. W. Touchberry. 1988. Wild horse parentage and population genetics. Final research report to the U.S. Department of Interior, Bureau of Land Management, January 15. University of California at Davis. Photocopy.

TABLE 2-3 Foal Paternity in Harem Bands

	Trap Site									
Type of Band	F	W	B	SC1	CA1	CA2	Total	Per-cent	Total[a]	Per-cent
Harem bands	12	10	12	20	8	7	69		45	
Bands, 1 stallion	9	4	10	12	6	1	42		23	
Excluded for all foals	3	0	4	4	1	0	12	29	5	22
Sire of all	6	4	3	6	4	0	23	56	14	61
Sire of some, not all	0	0	3	2	1	1	7	26	4	27
Bands, 2 or more stallions	3	6	2	8	2	6	27		22	
Excluded for all foals	2	2	0	0	0	2	6	22	4	18
One is sire of all	1	3	2	4	2	2	14	52	11	50
One is sire of some	0	1	0	4	0	2	7	25	7	32
Foals in band with stallion	18	11	23	40	16	13	121		80	
Without qualifying sire	7	3	9	15	2	4	40	33	24	30

NOTE: Study area designations are F, Flanigan; W, Wassuks; B, Beaty Butte; SC1, Stone Cabin/site 1; CA1, Clan Alpine/site 1; CA2, Clan Alpine/site 2. Stone Cabin/site 1 was located in west central Nevada, Nye County. Clan Alpine/site 1 was located in west central Nevada, Churchill County; site 2 was located in the same area, about 10 miles away.

[a]Considering only W, SC1, CA1, and CA2 sites for which no recent Bureau of Land Management roundups had occurred.

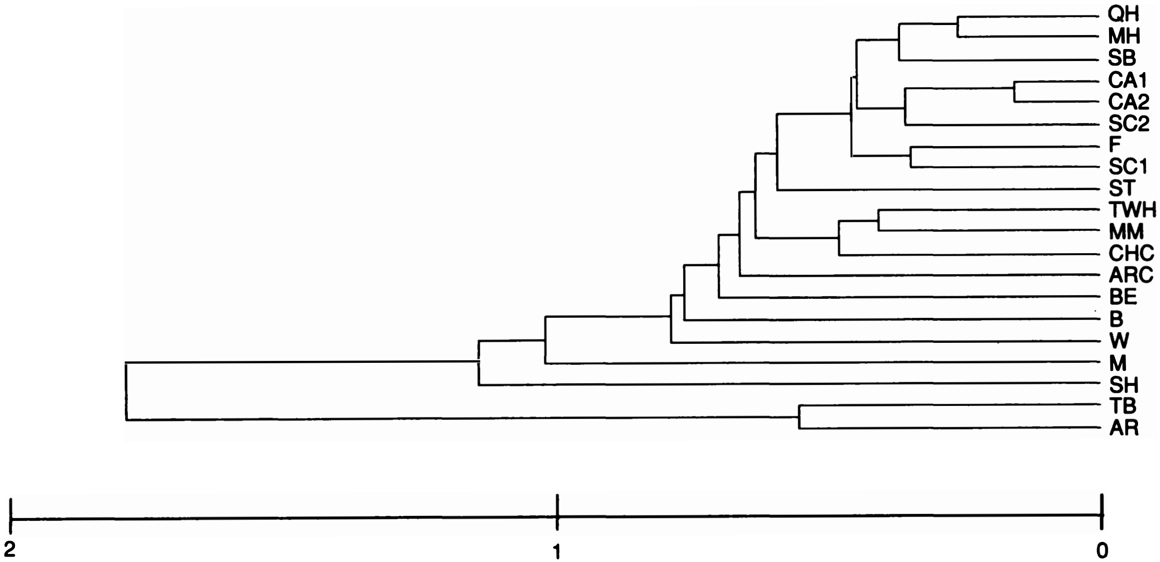

FIGURE 2-2 Nei's genetic distance for 20 horse populations. Source: A. T. Bowling and R. W. Touchberry. 1988. Wild horse parentage and population genetics. Final research report to the U.S. Department of the Interior, Bureau of Land Management, January 15. University of California at Davis. Photocopy.

Note: Designations are QH, quarter horse; MH, Morgan; SB, American saddle horse; CA1, Clan Alpine/site 1; CA2, Clan Alpine/site 2; SC2, Stone Cabin/site 2; F, Flanigan; SC1, Stone Cabin/site 1; ST, standardbred; TWH, Tennessee walking horse; MM, Mangalarga; SH, shire; TB, thoroughbred; and AR, Arabian. Clan Alpine/site 1 was located in west central Nevada, Churchill County; site 2 was located in the same area, about 10 miles away. Stone Cabin/site 1 was located in west central Nevada, Nye County; site 2 was located in the same area, about 10 miles away.

In summary, the genetic data support the domestic origin of these Great Basin horse populations, the lack of differentiation within or between these populations, and their likely origin from a substantial number of founders, with no evidence of a bottleneck or loss of heterozygosity. Because of their substantial sample sizes and high levels of polymorphisms, these studies are very robust and allow substantial confidence in the interpretations. The interpretations, however, apply only to the populations sampled. It is possible that there are other populations that have experienced a long history of isolation, small population sizes, or selective origins. The methodology and data base are now available to allow testing of any such proposed population.

MARE FERTILITY CONTROL STUDIES AT LOVELOCK CORRALS

The overall goal of the fertility control research has been to develop a method to block reproduction in wild and free-roaming horses that would be effective over several years. The research involved vasectomizing dominant band stallions or using steroid hormones to block pregnancy in mares. The research was initiated in the fall of 1985 with a corral study to develop methodology that could be used in the field in 1986 with wild and free-roaming animals. The objectives of the corral studies in Lovelock, Nevada, were to develop dosage levels and techniques for administering steroids to captive wild mares. Such dosages and procedures had not previously been developed in horses, and were needed before the research team could administer steroids to wild and free-roaming mares in the field. These studies at the Lovelock corrals were conducted by researchers from the University of Minnesota.

The relative merits of surgical implants versus remote delivery of steroids were considered. The advantage of remote delivery is that, operationally, the steroids could be administered in the field with darts fired from helicopters without subjecting the mares to capture, anesthesia, and surgical implant. However, the decision to use implants was made for the following reasons:

- The implantation procedure has been used with other animals, including humans, with success in multiyear fertility control.
- At the time research began in the fall of 1985, no studies using remote delivery had achieved more than 1 year of fertility control, nor was any technology known that would allow multiyear dosage.
- No dosage levels of remotely delivered female hormones were known.
- It was necessary to capture the experimental animals in the field in order to determine their ages and to mark them for subsequent observation. Hence, capture and restraint were necessary for either implants or remote-delivery animals.

Methodology

The first phase of the pen studies involved the development of silastic rods—silicone rods impregnated with progesterone or estradiol—to serve as the dosage delivery vehicle. The rate of release of the steroid was measured by testing this release periodically when the silastic rods were immersed in saline solution.

The first set of steroid implants in corraled males was initiated in mid-November 1985 and involved administering six different treatments to 30 mares each. These treatments involved the subcutaneous insertion in the neck of rods containing one of the following dosages:

- 8 g estradiol;
- 24 g progesterone;
- 8 g estradiol and 8 g progesterone;
- 12 g progesterone and 4 g estradiol;
- 12 g progesterone and 2 g estradiol; and
- placebos containing no steroids.

A seventh group of 30 mares was maintained as nonimplanted controls.

A second experimental sequence on corralled horses was initiated in April 1986 involved the seven dosages listed below using one of the following methods: subcutaneous implants in the rump and flank areas, intermuscular implants, and intraperitoneal insertion. Ten mares were used in each of the following treatments:

- 36 g progesterone and 24 g estradiol-17β;
- 36 g progesterone, 24 g estradiol-17β and glycerol;
- 36 g progesterone and 12 g estradiol-17β;
- 36 g progesterone and 12 g estradiol benzoate;
- 36 g progesterone and 8 g ethinylestradiol;
- 36 g progesterone and 8 g ethinylestradiol in methyl ether; and
- 1 g levo norgestrel.

The third series of treatments of corralled horses was run in January 1987 involving 50 mares for the following five treatments:

- 10 pregnant mares given 8 g ethinylestradiol;
- 10 pregnant mares given 3 g ethinylestradiol and 36 g progesterone;
- 10 open mares given 1.5 g ethinylestradiol;
- 10 open mares given 36 g progesterone and 8 g ethinylestradiol; and
- 10 open mares given 8 g ethinylestradiol.

Dr. Gerald M. Peck, the veterinarian under contract to the BLM during the Lovelock studies, was present during the surgical work to oversee the procedures.

Blood samples were taken at bi-weekly intervals from veins of the experimental animals to assay the amount of hormone released by the implants. To indicate the length of time over which fertility was controlled, blood samples were taken from November 1985 through November 1988. Normally, ovulation in horses is followed by an elevation of serum progesterone greater than 1.5 μg/ml. This elevation persists for 10 to 14 days and can be detected through bi-weekly sampling. This correlation of ovulation and elevation of serum progesterone has been validated by rectal palpations in domestic horses (Ginther, 1979) and, to a more limited extent, in feral horses (Wolfe et al., 1989). The failure to observe pregnancy despite elevated progesterone levels in some animals may reflect either the use of too rigorous a criterion to accept ovulation, or the fact that estrogens may exert a contraceptive effect at the level of the fallopian tube (delays migration of ovum or embryo into uterus) and of the uterus in antagonizing the progestational changes necessary for implantation.

Results

The first series of implants proved to be ineffective in preventing pregnancy when the mares were exposed to stallions during their normal estrus periods. In addition, some of the mares rubbed the implants out of their necks.

The second and third series proved more effective.

- Implants containing 36 g of progesterone plus 8 g of ethinylestradiol or implants containing 36 g of progesterone plus 24 g of estradiol-17β with glycerol as a cosolvent effectively blocked ovulation for two breeding seasons in more than 60 percent of the mares.
- Implants containing 8 g of ethinylestradiol without progesterone were capable of blocking ovulation for at least one breeding season.
- Implants containing 8 g of ethinylestradiol with or without 36 g of progesterone when implanted during mid-pregnancy allowed the successful completion of pregnancy and delivery of apparently normal foals.
- Scarring around the implants may be a significant problem that could reduce the longevity and effectiveness of the implants.
- Route of administration had no effect on the level of hormone achieved in the serum and consequently on the effectiveness of the implant.

Pregnancy was blocked through two breeding seasons in more than 90 percent of the animals receiving 36 g progesterone plus 8 g ethinylestradiol, or those animals receiving 8 g ethinylestradiol alone. Pregnancy was blocked through the peak of the breeding season of the third year in more than 70 percent of the animals receiving 36 g progesterone plus 8 g ethinylestradiol or 36 g progesterone plus 24 g estradial-17β and glycerol.

Over 80 percent contraceptive efficiency was achieved through the peak of the second breeding season in open mares that had been treated with 1.5 g ethinylestradiol alone or in pregnant mares that received 3 g ethinylestradiol plus 36 g progesterone. Moreover, the data show that ethinylestradiol at 1.5 g and 3.0 g blocks pregnancy without blocking ovulation, whereas 8.0 g of ethinylestradiol with or without 36 g of progesterone blocks ovulation as well as pregnancy. The data also suggest that 36 g of progesterone plus 24 g of estradiol-17β with glycerol blocks ovulation during the second year, but in the third year the treatment blocks pregnancy while allowing ovulation. More generally, the following conclusions were drawn:

- Effective contraception can be achieved for at least 28 months.
- The length of time that the contraceptive is effective beyond 28 months is not known.
- The mechanism of contraceptive effect is not completely understood. Ovulation could be blocked at the higher concentrations of ethinylestradiol or estradiol with or without progesterone. Or, at lower concentrations of ethinylestradiol, the contraceptive effect might occur at some point after ovulation, such as fertilization or implantation.
- The peritoneal cavity (intraperitoneal) is an efficient and effective location for routine implantation of hormonal contraceptives.

The experimental animals were removed from the Lovelock corrals in 1989 and transported to a wild horse sanctuary in Oklahoma after the steroid levels in their blood had been monitored for about 2 years. They are a valuable resource for establishing the length of time over which the implants are effective. Modeling the cost-to-effectiveness ratio of contraception versus roundup for horse population control depends on the number of years a treatment works. At present, the treatments are contraceptive up to 28 months, but it is not known how much longer they might remain effective.

Hence, the committee recommends that annual monitoring of blood hormonal levels continue until the levels are not significantly higher than the initial control levels. The cost of this monitoring would be low relative to the value of the results in determining the practical utility of contraception.

The committee concludes that the pen studies at the Lovelock corrals achieved their objectives and were handled in a professional manner. These chemosterility studies have led to the following publications in peer-reviewed literature: Plotka et al., 1987; Plotka et al., 1988a,b; and Plotka et al., 1989. At the time of its development, the intraperitoneal approach was on the cutting edge of a rapidly developing technology.

MARE FERTILITY CONTROL STUDIES IN THE FIELD

Steroid implants in the field constitute the second component of the mare fertility control experiments. The objective is to implant mares in selected study areas with steroids and placebos, follow their reproductive histories over 2 to 3 years, and evaluate the effectiveness of the treatments. Research is expected to be completed by the fall of 1990.

Methods

Wassuks Study Area

In January 1986, 41 mares, 3 years old and older, in the Wassuks area of west central Nevada were implanted with silastic placebo rods to serve as undosed comparison animals. These mares and those in the Clan Alpine area (described below) are not formal control animals. The horse populations in these areas are not large enough to support the formation of control groups and treatment groups. Therefore, separate or adjacent areas were used to compare treated and untreated mares.

The 41 placebo-implanted mares in the Wassuks area were equipped with radio collars. An additional 62 mature male and female animals were fitted with marker collars. The marker collar animals at this and other sites were intended to be used to study band stability and structure. This portion of the study was eventually discontinued because of the lack of funds.

Since many of these animals must have been pregnant from the 1985 breeding season, any possible blocking effect on future conception and pregnancy by the placebo would not be observable until the spring or summer of 1987.

Stone Cabin Study Area

In September 1986, 101 mature mares in the Stone Cabin area of south-central Nevada were implanted either with the 8 g ethinylestradiol plus 36 g progesterone (EP) combination (51 mares), or with 8 g ethinylestradiol (EE) only (50 mares). The 101 treated animals were equipped with radio collars. An additional 114 mature male and female animals were fitted with marker collars.

Many of these animals were undoubtedly pregnant from the 1985 breeding season. Hence, any blockage of future pregnancies by the steroids would not occur until the 1987 breeding season and would not be observable until the spring and summer of 1988.

Clan Alpine Study Area

In September 1987, 100 mature mares in the Clan Alpine area of central Nevada were implanted either with the 8 g ethinylestradiol plus 36 g progesterone combination (50 mares), or with 8 g ethinylestradiol only (50 mares). Forty-nine mares were implanted with placebos to serve as untreated comparison animals. All 149 treated animals were equipped with radio collars. An additional 152 adult male and female animals were fitted with marker collars.

Many of these animals were undoubtedly pregnant from the 1987 breeding season. Hence, any blockage of pregnancy as a result of the steroids would not occur until the 1988 breeding season and only be observable by spring and summer 1989.

Aerial Surveys

Four aerial surveys by helicopter were made in each study area each spring between the months of April and June. The purpose of these flights was to observe the foaling rates of treated and placebo-implanted mares.

Results

The results of the 1988 and 1989 aerial surveys are summarized in Tables 2-4, 2-5, and 2-6. Table 2-4 presents the foaling rates in 1988 for each study area and Table 2-5 presents the foaling rates in 1989. Table 2-6 compares the data from each year.

In the Clan Alpine area, where no treatment effects were expected until 1989, 97 of the 100 treated mares were observed in 1988 (Table 2-4). Of the 97 treated mares, 51 (53 percent) were seen with foals. Thirty-one of the 49 placebo implants were observed and 13 (42 percent) were seen with foals. Among an estimated 109 untreated mares with marker collars observed during the aerial observations, 51 (47 percent) were seen with foals.

In the Stone Cabin area where mares had been treated in the fall of 1986 and any treatment effect would have been evident in 1988, 88 of 101 treated mares were observed (Table 2-4). Of the 45 EE-treated mares and 43 EP-treated that were seen during the flights, 5 (11 percent) and 3 (7 percent) were seen with foals, respectively.

In the Wassuks, where 41 mares had received placebo implants, 15 (45 percent) of the 33 mares observed were seen with foals (Table 2-4).

Clan Alpine and Wassuks percentages are remarkably close, and none is statistically different from the others. They indicate that neither the roundup and treatment of the previous September in the Clan Alpine area nor the implants (placebos or steroids) in the Wassuks and Clan Alpine areas caused any statistically detectable signs of abortion or early foal mortality. A proportion of the animals were pregnant at the time of implantation, and the percentages of the four groups seen with foals are approximately what would be expected in a sample of undisturbed 3- to 12-year-old mares.

For 1989 in Clan Alpine, 4 (9 percent) of the observed 45 EE mares and 3 (6 percent) of the observed 50 EP mares were seen with foals. Of the 31 observed placebo mares, 14 (45 percent) were seen with foals. In Stone

TABLE 2-4 Foaling Rates as Determined by Aerial Observation, 1988

Area and Treatment	Number of Mares	Number of Foals	Foaling Rate	95 Percent Confidence Interval[a]
Clan Alpine				
Treatment[b]	97	51	.53	.43–.63
Placebo	31	13	.42	.25–.59
Untreated, marker collared[c]	109	51	.47	.38–.56
Stone Cabin				
Ethinylestradiol	45	5	.11	.02–.20
Ethinylestradiol and progesterone	43	3	.07	.00–.15
Wassuks				
Placebo	33	15	.45	.28–.62

[a]The 95 percent confidence intervals were calculated by the formula $p \pm 1.96(pq/n)^{.5}$, where p is the proportion of mares with foals and q is the proportion of mares without foals.

[b]Treatments in the Clan Alpine mares were not effective until 1989.

[c]This estimate is based on an aerial survey (third census) of the Clan Alpine study area (May 21, 1988). In Clan Alpine, 413 adults (yearlings or older) were captured, 149 of which were females 3 to 12 years old and were implanted with treatment capsules or placebos. The proportion of mares in that sample was 149/413 = .36. On May 21, 1988, 301 adults were counted in bands with no marked horses. Assuming the same distribution of mares as in the collared sample (.36), 109 of the 301 adults were mares in the 3- to 12-year age class.

In Clan Alpine, 66 foals were assigned to collared mares, 56 (.85) to 3- to 12-year-old mares and 10 (.15) to older mares. On May 21, 1988, 60 foals were counted in bands with no marked horses. Assuming the same distribution of foal production as in collared mares, 51 of the 60 foals were attributed to the 109 unmarked 3- to 12-year-old mares (Siniff et al., 1988a,b).

Cabin, 1 (3 percent) of the observed 35 EE mares and 6 (16 percent) of the observed 37 EP mares were seen with foals. In the Wassuks, 21 (70 percent) of the observed 30 placebo-implants were seen with foals (see Table 2-5).

The effects of the Clan Alpine steroid treatment were now evident in 1989 as were the Stone Cabin treatments for the second year. Meanwhile, the placebo implants bore foals in 1989 at about the same rate as in 1988. (In the Wassuks data the 95 percent confidence intervals around the foaling rate of 70 percent in 1989 overlap the 95 percent confidence intervals for

TABLE 2-5 Foaling Rates as Determined by Aerial Observation, 1989

Area and Treatment	Number of Mares	Number of Foals	Foaling Rate	95 Percent Confidence Interval[a]
Clan Alpine				
Ethinylestradiol	45	4	.09	.01–.17
Ethinylestradiol and progesterone	50	3	.06	.00–.12
Placebo	31	14	.45	.27–.63
Stone Cabin				
Ethinylestradiol	35	1	.03	.00–.09
Ethinylestradiol and progesterone	37	6	.16	.04–.28
Wassuks				
Placebo	30	21	.70	.53–.86

[a]The 95 percent confidence intervals were calculated by the formula $p \pm 1.96(pq/n)^{.5}$, where p is the proportion of mares with foals and q is the proportion of mares without foals.

1988, and thus the foaling rates for 1988 and 1989 at Wassuks are not statistically different.)

For the combined areas and years (Table 2-6), the percentage of observed, treated mares seen with foals varied between 6 percent and 11 percent. If the 1988 and 1989 data for each of the two treatments are pooled, the effectiveness in curbing reproduction is essentially the same: 8 percent for 125 EE-treated mares, 9 percent for 130 EP-treated mares. The percentages compare with 49 percent and 57 percent for the 2 years in the placebo implants. Evidently both EE and EP implants effectively reduce pregnancy rates in mares for at least 2 years.

By pooling all of the data, 22 (9 percent) of 255 observed, treated mares were seen with foals, while 114 (51 percent) of 222 observed, placebo-implanted mares were seen with foals.

The obvious and consistent difference in the very low fertility of the hormone-treated horses compared with the placebo-treated or untreated horses cannot easily be attributed to any other cause but the hormone treatment. The horses in the Wassuks study area serve as comparisons to the hormone-treated animals in the study. The placebo-treated horses in the Clan Alpine study area, which were originally recruited from the Augusta Mountain area, are also consistent comparisons to the hormone-treated horses. The measure of fertility in the placebo-implanted and untreated horses is consistent

TABLE 2-6 Pooled Foaling Rates

Year and Treatment	Number of Mares	Number of Foals	Foaling Rate	95 Percent Confidence Interval[a]
1988				
Ethinylestradiol (EE)	45	5	.11	.02–.20
Ethinylestradiol and progesterone (EP)	43	3	.07	.00–.15
Placebo[b]	161	79	.49	.41–.57
1989				
Ethinylestradiol (EE)	80	5	.06	.01–.11
Ethinylestradiol and progesterone (EP)	87	9	.10	.04–.16
Placebo	61	35	.57	.45–.69

[a]The 95 percent confidence intervals were calculated by the formula $p \pm 1.96(pq/n)^{.5}$, where p is the proportion of mares with foals and q is the proportion of mares without foals.
[b]Clan Alpine treatments combined with placebo implants in 1988.

with generally observed foaling rates of wild horses, and the difference between them and the hormone-treated mares is clear and consistent in all test areas.

VASECTOMY EXPERIMENTS

The research on reproductive inhibition was designed to experiment with both stallion and mare fertility control. Because the objective is to achieve as many years of inhibition as possible, the decision was made to use vasectomy for stallion fertility control. In order to achieve treatment efficiency, the approach was to vasectomize dominant stallions in bands on the assumption that this would curtail reproduction in the bands.

This assumption carries with it several often-unstated conditions if the procedure is to be effective:

- The dominant stallion must do all or most of the breeding in the band. If a significant amount is done by the subdominant stallions, the effectiveness of sterilizing the dominant is diminished.
- Bands must be relatively stable. If there is a significant exchange of mares or stallions between bands with vasectomized and intact stallions, the technique's effectiveness is reduced.

- Stallions must retain their dominance for several years. If dominance is highly transitory, then one-time sterilization of the dominant stallions of bands can be of only short-term effectiveness.

Methods

The Flanigan and Beaty Butte areas were selected for the vasectomy experiments. In the Flanigan area in northwestern Nevada, dominant stallions from 20 bands were vasectomized and fitted with radio collars; 5 dominant stallions from 5 other bands were radio-collared and left intact as comparison animals; and 139 3-year-old or older animals from these 25 bands were given plastic marker collars. These treatments were administered in December 1985.

In February 1986, 20 dominant stallions were vasectomized in the Beaty Butte area in the southeast corner of Oregon. An additional 67 animals, 3 years old and older, including 5 dominant stallions as comparison animals, were fitted with marker collars.

In the spring of 1988, four aerial surveys were conducted by the research team in the Flanigan area and three in the Beaty Butte area. One survey of the Beaty Butte area was cancelled because of low clouds and high winds. Behavioral observations of horses continued during the spring and summer of 1988. The aerial surveys in the spring of 1988 were the last scheduled surveys for the stallion areas, and aerial data collection for these areas is now complete.

Results

Preliminary results of the stallion study are summarized in Table 2-7. Dominant vasectomized stallions were classified by whether they were (1) in stable bands where they remained dominant, (2) in unstable situations where they were switching bands, or (3) in stud bands. They were further classified as to whether any foals had been born into their bands that year. Examination of these data suggests that sterilizing dominant stallions may have been effective in diminishing reproduction in mountainous habitats, such as the Flanigan area. However, its effectiveness in the flat Beaty Butte area, where bands of horses regularly mingle, is less certain. Final recommendations on the effectiveness of sterilizing dominant stallions will be delayed until thorough analysis of aerial survey data and ground behavioral observations is complete.

In the committee's view, vasectomy is an acceptable and effective method of sterilizing individual wild horses. However, several questions remain regarding its effectiveness as a long-term, population control procedure.

Even though a dominant stallion may be vasectomized and sterile, will

TABLE 2-7 Status of Vasectomized Stallions as Determined by Aerial Observation, 1986 to 1988

Study Area and Stallion Code Number	Year of Observation 1986	1987	1988
Flanigan			
201	Stable, foals	Stable, no foals	Stable, no foals
202	Unstable		Stable, no foals
204	Unstable	Stable, no foals	Stable, no foals
207	Stable, foals		
209	Stable, foals		
211	Unstable		Stable, foals
216	Stable, foals	Stable, no foals	Stable, no foals
219	Stable, foals	Stable, no foals	
523		Stable, no foals	Stable, no foals
529		Stable, no foals	Stable, no foals
Beaty Butte			
520	Stable, foals	Stable, foals	
521	Unstable		
532	Unstable		
537	Unstable	Stable, no foals	Stable, no foals
696	Unstable	Unstable	Stable, foals
697	Unstable	Stud band	Stud band
701	Unstable	Unstable	Unstable
719	Stable, foals	Unstable	
732	Stable, no foals	Unstable	Stud band
734	Unstable	Stable, no foals	Stable, foals
735	Stable, foals		
738	Stable, no foals		
739	Unstable	Stable, no foals	Stable, no foals
744	Stable, foals	Unstable	
747	Stable, foals	Stable, foals	Stable, foals
750	Stable, foals	Stud band	Stud band

SOURCE: Siniff, D. B., J. R. Tester, T. C. Eagle, R. A. Garrott, and E. D. Plotka. 1988a. Fertility control in wild horses. Progress report to the U.S. Department of the Interior, Bureau of Land Management, November 30. Table 2. University of Minnesota and Marshfield Medical Foundation. Photocopy.

subordinate males in the band assume the duties of the dominant male and sire foals? How many foals are actually produced by mares in bands where the dominant stallion has been vasectomized?

Again, the data in Table 2-7 give ambiguous answers to these questions. In the Flanigan area, observations of the bands associated with a vasectomized dominant stallion showed six stable bands with no foals out of the six bands that were observed in 1987 and only one stable band out of the seven observed in 1988 that did have foals.

But in the Beaty Butte area, in 1987 there were two bands with foals out of the five stable bands observed, and in 1988 there were three that contained foals out of the five stable bands that were observed that year. Other bands at Beaty Butte that were observed to include a vasectomized stallion during these 2 years were either unstable or stud bands.

Moreover, in the genetics studies reviewed above, approximately one-third of the foals in the sample bands were not sired by the dominant stallion *of that year*. Either mares were moving between bands or the sub-dominant males were siring young. Because Berger (1986) has also reported that stallions of differing social status mate with mares, there is reason to withhold judgment on one-time stallion sterilization as a general fertility control procedure.

Vasectomizing the dominant stallion is likely to extend the breeding season. Wild horse mares come into estrus every 21 days, from April through September. Once the mare becomes pregnant this cycle stops, and the stallion does not have to mate with this mare or defend her from other interested stallions. Therefore, another question arises. Will the vasectomized dominant stallion be undernourished as winter arrives because of the additional time and energy required to guard mares during estrus?

The evidence so far indicates that this is not the case. It appears that vasectomized stallions graze sufficiently to maintain body weight and survive the winter satisfactorily.

Does an extended breeding season give the subordinate males more opportunities to breed the recycling females? And if so, do the mares become pregnant and produce foals? Berger (1986) found that stallion dominance was transitory, changing between years. This substantially diminishes the prospect that one-time vasectomy is a population control procedure that would remain effective over a period of years.

These and possibly other factors must be weighed before conclusions can be reached on the efficacy of dominant-stallion vasectomy as a population control technique. On-site behavior observations also need to be integrated into the overall evaluation. At this point its efficacy looks doubtful.

3

Computer Simulation Studies

Although not part of the contract between the Bureau of Land Management (BLM) and the University of Minnesota, the research group engaged in computer modeling to compare the population control effectiveness and costs of various roundup and fertility control options. The group presented its results to the committee at the February 1990 review in Denver.

The researchers modeled the following three, herd management scenarios over a 20-year period:

1. The roundup and adoption procedures used to date. This scenario assumed that a hypothetical herd would need to be rounded up every 4 years. Initial herd size was 600, and at each roundup it would be reduced to 300. The captured horses would then be placed for adoption. Costs were assigned to roundup transportation, holding, and adoption based on BLM's records.
2. Mare contraception. An initial herd of 600 would be reduced to 300 through roundup and adoption. All of the mares that were older than 3 years would be implanted with estrogen. Every 3 years thereafter, enough animals would be rounded up to implant 85 percent of the mares more than 3 years of age.
3. Contraception and selective removal. An initial herd of 600 would be reduced to 300, and the removals placed for adoption. All of the mares older than 3 years would be implanted with estrogen. Every 3 years thereafter, enough animals would be rounded up to implant 85 percent of the mares older than 3 years, and all of the animals 1 to 3 years old would be removed and placed for adoption.

The model predicted that scenarios 2 and 3 would cost 30 to 50 percent less than scenario 1. Furthermore, they would significantly reduce the number of animals needing to be adopted and ameliorate the chronic problem of holding unadoptable animals. The major drawback is that the horses would be captured and handled more frequently in order to implant the mares every 3 years. Hence, the modeling shows that there would be trade-offs, but nonetheless a distinct gain in costs and a reduction in the problems associated with the roundup and adoption program.

As in any modeling exercise, the output is contingent on assumptions made. The Minnesota investigators caution that anyone substituting alternate assumptions, or modifying the simulated protocols, must not expect the same results as those encapsulated above.

4

Research Concerns

Numerous problems confront researchers who study feral horses, and two major logistical problems are inherent in the western United States. First, the rugged, mountainous nature and extensive size of most potential study areas create dilemmas in sampling study animals. It can be difficult to coordinate a large team of biologists to study each of the many populations, although detailed life history and reproductive data can be gathered in this way (Berger, 1986). Depending on available funding, the only feasible method for gathering data over multiple, large study areas is aerial observation. Second, and more important, is the selection of suitable study areas. As pointed out by Berger (1986), several researchers were forced to terminate their projects because study animals were removed by the Bureau of Land Management (BLM) before the studies were completed. The BLM's mandate to manage feral horse herds has made difficult the selection of study areas that fulfill requisites for data collection. In Nevada this problem has been serious, and it has been necessary to select study areas that minimize these conflicts.

Concerns about the conduct of field research activities have been addressed in the following five areas:

- Loss of the Clan Alpine horses;
- Problems and injury with the marker and radio collars;
- Foal orphaning and loss during roundups and aerial surveys;
- Abortion; and
- Disappearance of the penned animals at the Lovelock corrals.

To an extent, these concerns reflect differing views of the ethical acceptability of the methods used to study population control in wild and free-roaming horses. Examination of these ethical concerns, however, are beyond the professional expertise and charge of the committee. The committee can respond to these issues only as they affect the quality of the research results.

LOSS OF THE CLAN ALPINE HORSES

In late August and early September 1987, BLM representatives and the research team began to round up animals from the Clan Alpine area for experiments. However, by September 1 the number of animals rounded up was insufficient for a satisfactory sample size. A decision was made to augment the Clan Alpine numbers with animals from the adjacent Augusta Mountain area.

A fence separates the Clan Alpine and Augusta Mountain areas. On September 2 and 3, 133 animals were rounded up in the Augusta Mountain area and driven to a trap on the Clan Alpine side of the fence. Some horses were driven as far as 15 or 20 miles. The weather was hot and dry, and the horses were in relatively poor physical condition.

Of the 133 captured animals, 42 mares were implanted with placebo capsules and equipped with radio collars, bringing the total number of placebo-implanted mares in the Clan Alpine study area to 49. Another 33 were fitted with marker collars, bringing the total untreated, marker-collared population to 109. The animals were then released on September 2 and 3 in the vicinity of the trap.

Between September 17 and October 30, 48 horses were found dead on the Clan Alpine side of the boundary fence. These included 17 radio-collared animals, 11 animals with marker collars, and 20 unmarked animals. A team composed of a veterinarian and BLM law enforcement and management personnel investigated the situation and concluded the following (U.S. Department of the Interior, 1987):

> The animals were attempting to return North to their home range and were prevented from doing so by the fence. Therefore, not knowing where water sources were located south of the fence, the animals walked the fence in both directions until they died from dehydration.

The committee has received four other versions of the incident, including one account that there were no gaps in the fence and the horses were driven excessive distances around it.

The committee deeply regrets this tragic incident, but it is in no position to impute culpability. It bears, however, the responsibility to assess the effects of this incident on the validity of the research results.

The losses included 17 comparison mares with placebo implants. Another placebo-treated mare died about 12 hours after release, reducing the number of Clan Alpine comparison mares from the original 49 to 31. This reduced the statistical power of the test for the difference in that study area. Nevertheless, the foaling rate of the 31 observed placebo implants in this area in 1989 (Table 2-5) was statistically higher than that of the treated mares.

Moreover, for the study as a whole, there remained 30 comparison mares in the Wassuks in 1989. Thus the loss of the 18 Clan Alpine animals reduced the total number of comparison mares from 90 to 61. Given 2 years of observations on these animals and on the 1988 unmarked mares (Table 2-4), the loss did not render the research invalid or statistically inadequate. As discussed above, the foaling rates of the placebo implants in the different areas and years are consistently similar. Those rates are all statistically higher than the rates of the steroid-treated animals in their second and third years after implantation, and they are in a consistent, low range.

COLLAR PROBLEMS

The use of both radio and marker collars is a widely accepted practice in large-animal field studies. Based on extensive experience with these devices, no adverse effects were anticipated. Between 1987 and 1989, however, a number of horses involved in the study suffered injuries to their necks and ears that were caused by the collars used to locate and identify the experimental animals. Serious questions have been raised concerning the deaths of some of these animals, the nature and extent of the wounds, and possible changes in behavior of the animals as a result of collar problems. Other questions have focused on the design of the collars and the experience of the research team.

Collars were attached to a total of 876 horses. Of these 876 animals, 336 received radio collars (291 mares and 45 stallions); the other 540 adult horses were fitted with marker collars. The radio-collared animals were part of the two fertility control studies. The marker-collared animals were intended to be part of a study of band stability; this study was discontinued due to a lack of funds. The collars will be removed by the BLM at the end of the fertility control study.

Collar Design

The collars are made from an industrial belting material composed of rubber and canvas that is inelastic but somewhat flexible. They are 4 inches wide, with a narrower section underneath the neck where the radios are attached. The collars are adjustable in circumference by means of a system of holes and studs, but fine adjustments are difficult or impossible. Attachment of the radio units stiffens the collars, making them quite inflexible over a span of several inches. All of the collars have 3-inch high numerals to permit identification from the air. These collars are similar, although not identical, to ones employed successfully by members of the research team in an earlier wild horse census study. The belting material used for the collars in the present study appears to be less flexible than the material used previously.

Collar Wounds

Collars were first fitted in the fall of 1986, and problems arose in the spring of 1987. As soon as the problems became evident, the research team began searching for injured horses by helicopter with Dr. Gerald Peck, the on-site consulting veterinarian for the Nevada state office of the BLM. Animals that appeared from the air to have an injury needing treatment were darted and examined. The results are summarized in Table 4-1.

During the years from 1987 to 1989, the research team darted a total of 77 animals. Collars were removed from 54 animals, which constituted 6 percent of the 876 collared animals. Twenty-seven were removed because they were too tight; 27 others were removed because they became too loose and slipped forward over the animals' ears. Six animals were subsequently recollared.

A total of 48 animals had collars permanently removed. Twenty were radio-collared animals that formed part of the experimental population. Three additional radio collars slipped off animals in the field. In all, 23 animals were lost from the experimental population due to collar removal or loss. The other 28 collars that were removed were marker collars with no radio telemetry devices attached. Two other animals died while being captured to have collars adjusted or removed.

The wounds caused by tight collars were unquestionably grim in appearance. In some cases, the horse grew into the collar material, so that the collar became imbedded in the animal's neck. In other cases, the collar abraded the skin under the neck where the radio unit was attached, causing an open sore that subsequently became infected. Loose collars rode up on the animals' necks and over their foreheads, causing sores on the ears.

Primarily the injuries were surface wounds, which responded to treatment and healed. Dr. Peck told the committee that there was no sign of systemic infection, dehydration, or deterioration of body condition in the injured horses. Dr. Peck's diagnoses were communicated to BLM on January 25, 1988, in a report (see Appendix). Six of those animals (designated as recollared in Table 4-1) have subsequently had collars reattached. Dr. Peck, however, questioned the recollaring of horses with neck scar tissue; no animals were recollared after September 1988.

The great majority of the neck wounds were associated with radio collars, rather than marker collars. Most of the wounds occurred under the neck, at

TABLE 4-1 Darting and Collar Summary, 1987 to 1989

Time Period and Study Area	Number of Collared Horses					
	Horses Darted	Collars Removed	Collars Adjusted	Collars Not Adjusted	Horses Died	Horses Recollared[b]
June 1987-September 1988						
Flanigan	11/0[a]	9/0	2/0	0/0	0/0	0/0
Beaty Butte	1/0	1/0	0/0	0/0	0/0	0/0
Wassuks	4/0	4/0	0/0	0/0	0/0	0/0
Stone Cabin	4/31	2/18	2/10	0/2	0/1	0/6
Clan Alpine	4/4	0/2	3/1	0/1	1/0	0/0
Subtotal	24/35	16/20	7/11	0/3	1/1	0/6
October 1988-October 1989						
Flanigan	2/0	2/0	0/0	0/0	0/0	0/0
Wassuks	3/0	3/0	0/0	0/0	0/0	0/0
Stone Cabin	3/6	3/6	0/0	0/0	0/0	0/0
Clan Alpine	3/1	3/1	0/0	0/0	0/0	0/0
Subtotal	11/7	11/7	0/0	0/0	0/0	0/0
Total	35/42	27/27	7/11	0/3	1/1	0/6

[a]Number on left represents animals with collars over their ears; number on the right represents animals with tight collars.
[b]Six animals that had their collars removed were subsequently darted a second time so they could be recollared.

the point where the radio unit was attached. In two cases where the collar had rotated, wounds were observed on the mane under the radio unit. Most observers attributed this effect to the stiffening of the collars at the point where the radios were attached. Dr. Peck also pointed out that the radio collars were put on with the horses lying down, tied up, and anesthetized, while the marker collars were put on with the horses wide awake, and standing in the chute with their neck muscles tensed.

Stone Cabin

Most of the problems with tight collars occurred at Stone Cabin. Collars were placed on 215 animals (101 of which were radio collared) in September 1986. Between June 1987 and September 1988, 31 of those horses were subsequently identified as having collars that were too tight. The research team attributed the problems with tight collars at Stone Cabin to rapid weight gains. They stated that forage conditions were favorable, contraception was effective, and the animals experienced significant increases in body fat. BLM personnel generally agreed, pointing out that the horses at Stone Cabin were collared during the second year of a 2-year drought, which was followed by 2 years of high precipitation and abundant forage production. Both the researchers and BLM personnel stated that the problem of collars becoming imbedded had not happened before and was not anticipated on the basis of previous experience.

Age may also have been a significant factor. According to BLM personnel, many of the animals collared at Stone Cabin were young (2 to 5 years) and may have outgrown their collars in the normal process of maturation. One BLM official told the committee that virtually all of the horses from 2 to 5 years of age experienced collar problems. It is not possible to evaluate the effect of age in the absence of age distribution data. Dr. Peck also suggested that the hormone implants may have caused unusual weight gain in the treated mares.

In 1987, after neck wounds were first observed, seven animals were darted at Stone Cabin to treat collar sores. One collar was removed, and six collars were loosened. One animal was subsequently recollared. In 1988, 28 animals were darted to treat collar problems; 19 collars were removed, 6 were adjusted, 2 horses were released without adjustment, and 1 mare died as a result of recapture. Wounds were cleaned and treated with antibiotics. Collars were removed in cases where it was judged necessary to assist recovery, and the animals were released. Since October 1988, another six tight collars have been removed from the horses at the Stone Cabin study area.

Monitoring

The condition of the study animals and the fit of the collars are monitored from the air during the four census-taking flights scheduled as part of the original study design. In 1988, BLM added an additional flight to check for collar problems in the fall after the animals gained weight over the summer. These measures were applied to all of the study areas and continued in 1989. Dr. Peck recommended increasing the additional collar monitoring to four times a year at regular intervals to detect health problems in the collared horses. In his view, the current schedule of monitoring flights is not sufficient to identify collar problems before they become severe. However, several observers expressed concern that increasing the frequency of the monitoring flights, especially during the spring and summer, could increase the incidence of abortions or orphaning of foals.

Other Study Areas

The collar-related problems experienced at study areas other than Stone Cabin have been less serious (Table 4-1). Five animals were darted to treat complications from tight collars at Clan Alpine; no tight-collared animals were found at Flanigan or Beaty Butte. Of the five at Clan Alpine, two collars were removed, one was adjusted, and one was left in place without adjustment. Three additional collars were adjusted at Clan Alpine, and one animal died during recapture.

The Flanigan and Beaty Butte study areas involved vasectomized stallions only. Collars became loose on several of the experimental animals. In these cases, the collars rode up over the ears of the animals, causing abrasions and concern that they might interfere with vision, hearing, or normal behavior. To correct problems with loose collars, 11 horses were darted at Flanigan through September 1988; nine collars were removed and two adjusted. During the same period of time, one horse was darted at Beaty Butte and the collar was removed. Collars also fell off the vasectomized stallions. By September 1988, 13 of 20 vasectomized males in Flanigan no longer had collars because of removal or loss. In Beaty Butte, 7 of 20 collared animals either lost collars or had them removed. Two additional collared animals died in each area during the course of the study. Since October 1988, one tight collar was removed at Clan Alpine, while a total of eight loose collars were removed at Flanigan, Clan Alpine, and Wassuks. During the fall of 1988 and throughout 1989, the BLM and the research team followed a policy of removing all problem collars, whether or not there was any injury to the animal.

Behavior Effects of Collars

Questions have arisen about the effects of the collars on animal behavior, because the collars may restrict sight or hearing or inhibit normal behaviors such as ear signaling, nuzzling, or neck rubbing. Dr. Cheryl Asa, an animal behavior researcher from the University of Minnesota, told the committee that her field observations of vasectomized and control stallions in the Flanigan and Beaty Butte sites indicated that the collars themselves did not seem to impede normal behavior significantly and did not compromise the animals. In fact, Dr. Asa expressed a concern that loose collars were being adjusted unnecessarily. In her view, the risk from darting the animal to adjust the collar greatly exceeded any risk from the loose collar itself.

Mortality Caused by Collars

The research team has attributed two deaths to collar-related problems. The first was a 25-year-old mare that died at Stone Cabin after being darted to treat a tight collar. The second loss occurred when a stallion fell off a cliff after being darted at Clan Alpine.

Other animals with collars were found dead. One had a collar imbedded in its neck, but no cause of death was determined. Another animal was found dead 12 days after she had been darted but failed to succumb. She was judged to have been dead for 3 to 7 days. The causes of both of these deaths were classified as "other."

The research team classified as natural the deaths of an additional 21 collared horses (4 with marker collars and 17 with radio collars) that were found dead before August 1988. The team found no evidence that these collars were stained from drainage, as were those that had become embedded in the horses' necks before removal. BLM observers believe that collar-related wounds may have caused or contributed to the deaths of at least some of these animals. It is not now possible to determine if the collars played a role in any of these deaths.

Effect on Statistical Adequacy

Questions have arisen regarding whether deaths and collar removals reduced the sample sizes to the degree sufficient to compromise the statistical validity of the study.

A total of 273 mares and 45 stallions in the experimental populations survived roundup and initial collaring. Eighteen placebo-treated mares died at Clan Alpine shortly after being rounded up and collared. The stallions were collared first, and subsequent collar problems with males involved loose collars that slid up over the animals' ears. By the end of the study period, 13 of 20 vasectomized animals in the Flanigan site had lost collars and 2 others had died. In Beaty Butte, 7 of 20 lost collars over the course of the study and 2 other collared animals had died. This gradual loss of collars and a lack of controls throughout the vasectomy study make the results of the vasectomy experiments difficult to interpret.

Tight collars were a problem only with mares. Of the 273 collared mares in the fertility study, 23 or 8.4 percent were lost from the experimental population due to collar removal or loss. An additional 17 horses with radio collars, or 6 percent, died of natural causes during the study. Four other animals died during collaring procedures, and two more with collars were found dead but their deaths were classified as "other." It is not known whether these last six animals were wearing radio or marker collars.

The number of mares from which radio and marker collars were removed and not replaced and the number of collared animals that died total 76, or 9 percent of the number originally collared. As discussed above and summarized in Tables 2-4 and 2-5, the number of animals in each treatment block both in 1988 and 1989 was sufficient to establish statistically significant differences between treatments and placebo implants in all of the cases. Regaining the animals lost to the study would not significantly strengthen the results of the research or the statistical significance of the inhibiting effect of the implants on reproduction.

Summary

To the extent possible, the committee has assessed the problems experienced with the radio and marker collars. There is no doubt that some of the collared animals suffered large and painful wounds, and at least two horses died as a direct result of problems with their collar adjustment. Twenty-three radio-collared horses were lost from the observable population because of collar removal, and two others died while being recaptured to remove their collars. Marker collars were removed from another 28 horses that were not included in the study population. No horses are known for certain to have died from collar wounds.

The collar problems have been attributed to various causes, which include: the design of the collars; the material and construction of the collars; irritation caused by the radio units; tight or loose fitting collars; natural growth of young horses; rapid weight gain because of abundant forage; abnormal weight gain as a result of the hormone implants; and difficulty in making fine adjustments at the first collar fitting. Most observers agree that most of the neck injuries were related to the radio units.

The collars were based on a generally accepted design. Similar collars have been used successfully in field studies of wild and free-roaming horses and many other species of large animals. The research team has had extensive experience with collars, telemetry, and fieldwork of this nature. Based on prior experience, the problems with collars experienced in this study were not anticipated.

Both the research team and the BLM responded as collar problems were observed. Animals with collar wounds were recaptured, and the wounds were treated and the collars removed as necessary. Treated injuries have healed, and some of the collars have been replaced. Additional flights were made to locate horses with collar injuries, and BLM added a fall flight to the monitoring schedule to check the condition of the horses after the period of summer weight gain.

Problems with collar injuries could continue during the remaining months of this study because the construction of the collars, the radio units, and the potential for weight gain remain unchanged. However, because the research team and BLM are now more intensively monitoring the problem, future injuries should be reduced in both incidence and severity. The BLM will round up all collared animals after the 1990 observation season and remove the collars.

FOAL ORPHANING AND LOSS

Questions have arisen over whether the spring and summer monitoring flights, to assess the reproductive status of the mares, separate mares from their foals and cause foal orphaning or death. In the case of collared mares, the numbers on the collars must be read in order to determine whether they are steroid-implanted experimentals, placebo implants, or untreated mares that have been fitted with marker collars. In order to read the numbers, the helicopter must descend to a low altitude over the mares, and they must at times be chased some distance before the numbers can be read. The concern is that, in this monitoring process, mares and foals can be separated and may not be reunited. In such cases, the foals might be permanently separated from the mares at ages too young to survive on their own.

Prior to the committee's 1988 meeting in Reno, Nevada, the committee conveyed concerns to the research team arising from aerial monitoring and the associated risk of foal orphaning and death. At the meeting, the committee examined two sources of evidence provided by the research team to determine whether foal orphaning or loss was occurring.

The first source was the record of observations on collared mares to determine whether mares seen with foals in the initial spring flights were observed without young in subsequent flights. This record proved inconclusive because of ambiguous trends. For example, a mare that may have been seen with her foal in April and sighted twice in May without her foal may have been seen in June with her young. Because of the frequency of these cases, no general pattern of individual mares could be inferred.

The second source of evidence consisted of aggregating all of the flight observations and calculating the percentage of mares with foals seen in each study area. A decline through the four flight periods would suggest foal loss.

Trends were calculated for Wassuks and Stone Cabin in 1987, and Wassuks, Stone Cabin, and Clan Alpine in 1988. Here again, the results were inconclusive. Because the samples were small and individual flight results were therefore variable, trends were difficult to infer. Two areas showed a decline: Wassuks in 1987 between censuses 3 and 4, and Clan Alpine in 1988 between censuses 2 and 4. Stone Cabin in 1988, however, showed a slight, net increase between censuses 1 and 4. Stone Cabin in 1987 and Clan Alpine in 1988, although variable between censuses, showed no net trend between censuses 1 and 4.

In light of available evidence, the committee concluded that the monitoring did not appear to have caused heavy or consistent foal loss. This conclusion did not rule out the possibility that individual foals may have been lost. If such a loss occurred, however, it was not frequent enough to detect through aerial observations. In addition, some natural foal mortality is expected.

Earlier studies have shown that the foal stage is the period of highest natural mortality in the life of a wild horse.

The issue arose again after the 1989 field season, sparked by a memorandum (Sweeney, 1989) that was based on field observations by BLM employees who accompanied the research flights, in a separate helicopter, to identify collared mares and to observe foals. They recorded instances during 1989 when the BLM observers feared that foals may have been separated. After 17 flights over the Wassuks and Clan Alpine areas, one observer wrote, "In my opinion, at least five foals were likely permanently separated from their mares. . . . I believe that the [actual] number of foals [lost] . . . is greater than the five." Sweeney's memorandum concludes "an undetermined number are left behind to become orphaned."

The committee again raised the matter with the research group at the February 1990 review in Denver. In response, the researchers described the flight procedures as follows:

- No band is chased more than 400 to 500 yards. If a foal separates from a band, the research helicopter pulls out of the chase.
- If a foal is separated, the helicopter circles in front of the band and turns it back toward the foal.
- As a precautionary measure, all research flights are accompanied by a second helicopter containing BLM observers who are watching for excessive chases and foal separation. If these occur, they can radio the research helicopter and advise it to end the chase. BLM has never called off the research helicopter.

As in the 1988 review, the research group also reviewed the trends in percentages of observed mares with foals over the four successive flights in the three study areas in 1989. Here again, there were no consistent trends.

A review of available data did not support the assertion that a major, consistent loss of foals occurred. Some small number of foals could have been lost, although even this is not unequivocally shown.

The committee remains concerned about the possibility that the monitoring flights may be causing foal orphaning or loss, and urges that the research team proceed with caution. From the standpoint of the research protocol, both placebo- and steroid-implanted mares are equally at risk. Thus, to the extent there may have been some losses, a comparison of the fecundity of the steroid- and placebo-implanted mares is not invalidated.

ABORTION

Another concern is the possibility that roundup for treatment and subsequent-year censusing flights cause mares to abort. Some observers maintain that (1) abortion may be caused by the stress the animals endure under the research methods of roundup and censusing, and (2) abortion, if it occurs, might have a statistical impact on the research results with regard to the actual effectiveness of the contraceptive implants. Because of observed abortion in corrals following BLM herd-control roundups, an analogy has been drawn between these observations and the possible occurrence of abortion as a result of research-induced stress.

The research team has seen no fetuses or other evidence of abortion. Of course, this does not rule out the possibility of its occurrence. It simply may not have been seen.

However, as discussed above and in Table 2-4, the foaling rate of the Clan Alpine placebo-implanted mares in 1988 (42 percent) and that of the steroid-implanted mares (53 percent) were similar to the foaling rates of the untreated, marker-collared animals that were not approached closely by helicopter (47 percent). The Wassuks placebo-implanted mares also had a similar foaling rate (45 percent). All of these rates fall well within the 95 percent confidence intervals of each other.

These results do not entirely rule out the possibility of abortion. Relatively small samples and year-to-year and site-to-site variation could mask the occurrence of some abortions. However, given the similar foaling rates, if abortion is occurring, it is occurring at too low a rate to be measured statistically.

With regard to the integrity of the research methods and the validity of the results, steroid- and placebo-implanted mares are subject to the same conditions in the conduct of the research. However, because steroid-treated mares are expected to have fewer pregnancies, more abortions would be expected from the placebo-implanted mares. Therefore, abortion, if occurring, would narrow the difference between the foaling rate of the steroid group and that of the placebo group.

Because the foaling rate of the placebo-implanted mares in the Clan Alpine area was within the range of the comparative values of less disturbed, marker-collared mares in 1988, there is no reason to conclude that abortion resulted in a sufficiently narrowed difference between steroid and placebo groups to invalidate the experiment. In the absence of either (1) direct evidence or (2) a statistical indication of abortion resulting from study protocols, the committee concludes that the validity of comparing foaling rates in steroid- and placebo-implanted mares is not compromised by abortion, if any occurs.

DISAPPEARANCE OF PENNED ANIMALS AT LOVELOCK CORRALS

The claim has also been made that large numbers of experimentally treated animals disappeared in the Lovelock corrals. According to the researchers, however, the total number of missing animals was 13. The number of animals in this treatment group was 210 in the first series, 70 in the second, and 50 in the third. These groups were not mutually exclusive; some animals in the first series were used again in the second and third. Hence, the total number of experimental mares was something less than the sum of these three numbers. Nevertheless, the sample sizes were substantial and the disappearance of 13 animals does not pose a serious problem for the integrity of the experiments.

FOOD CHAIN RISKS FROM STEROIDS

Questions have been raised regarding the wisdom of releasing into the wild large numbers of mares with steroid dosages coursing through their tissues. These animals might eventually be rounded up and used for human consumption, or they might die and their flesh eaten by wild carnivores whose reproduction could be impaired.

The dosage trials in the Lovelock corrals were undertaken with estradiol, a natural estrogen that is chemically broken down by the digestive process if consumed by an animal. The first dosages administered were not effective. In the second and third series the estradiol dosages showed some effectiveness, but time was running out and an effective dosage was needed to treat mares in the field by September 1986, according to the schedule of the contract. Therefore, pen trails were begun with ethinylestradiol, a synthetic estrogen that is 30 times as effective as natural estradiol, but withstands digestion if consumed by an animal. This treatment proved effective both in pen- and field-treated animals.

As to the risk of consumption, the possibility of a treated animal being eaten is very small. Moreover, ethinylestradiol is the steroid commonly used in human oral contraceptives. Using liberal calculations, a human must consume 1 pound of horse flesh shortly after implantation (i.e., the peak level of steroid release) in order to ingest the amount of ethinylestradiol contained in a single, low-dose oral contraceptive pill. At some time after implantation, when the steroid release of the capsule had declined to its longer-term level, the amount ingested would be substantially less.

5

Conclusions and Recommendations

The following four conclusions are based on the data and information available to the committee as of April 1990.

1. The genetics studies show that in any given year about one-third of the foals in bands are not sired by the dominant stallion, and a high degree of heterozygosity exists in wild horses, which originated largely from domestic breeds in the Oregon and Nevada study areas.
2. The Lovelock pen studies have produced steroid dosages, a delivery vehicle, and a surgical procedure that block pregnancy in at least 70 percent of treated mares for at least 28 months. The treatment does not appear to cause abortion in mares that are pregnant when it is administered.
3. The dominant-stallion vasectomy study has had ambiguous results. The data suggest a reduced foal production in the Flanigan area in the first breeding season following surgery. However, the treatment was not effective in Beaty Butte. The research team is analyzing the data in greater depth.
4. The 1988 and 1989 field observations indicate that steroid implantation in mares effectively reduces foaling rates from the 40 percent to 50 percent levels observed in untreated and placebo-implanted mares, to a level of less than 10 percent for at least 2 years in steroid-implanted mares.

This research has been expensive, logistically difficult, and carried out under limiting financial and time constraints. The subjects are powerful, spirited animals that are difficult to handle and risk injury when penned or handled. To a considerable degree, the methodology has been developed anew, under difficult and risky environmental conditions. Fortunately, one helicopter crash during the course of the study did not result in any casualties.

Sadly, there have been injuries to and losses of animals. While regrettable, the numbers lost do not invalidate the results of the research. Overall, the committee feels that the research has been conducted professionally and as effectively as possible under the prevailing constraints and conditions.

The committee recommends continuing observations in the fertility control studies to determine how long the implants effectively control fertility. The implanted mares now held in the Oklahoma horse reserve should be maintained and their blood sampled annually until hormone levels are not significantly different from controls.

To determine the longevity and effects of implants in the field, field monitoring of steroid- and placebo-implanted mares should continue through 1990. Because of objections to helicopter use for this work, attempts should be made to obtain these data from the ground.

The use of chemosterilants in herd management should be evaluated in contrast to other viable control options, and not unduly discounted because of problems that occurred during field research experiments. The loss of 48 animals at the Clan Alpine study area, collar wounds, and possible foal orphaning were products of the research procedures. These problems would not occur normally during the routine application of fertility control for herd management.

The committee believes that the research to date shows some promise for controlling the wild and free-roaming horse population, and at reduced cost and need for adoption. The use of alternative methods is a decision to be made by the Bureau of Land Management (BLM). Clearly, major influences on BLM's decision will be the goals for the program and the resources provided by Congress to administer it.

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APPENDIX

Report on Collared Horses

The following is an unabridged version of the BLM report, Treatment of Collared Horses at the Stone Cabin Management Area, *written by Gerald R. Peck, D.V.M., on January 25, 1988.*

Horses with tight radio tracking collars were anesthetized by dartgun using M-99 in combination with xylazine and shot from a helicopter. Reversal of this combination was accomplished by intravenous injection of M-5050 and yohimbine. Only horses with collars showing signs of drainage from a wound or excessive tightness were darted. On January 16, 1988, 4 horses were anesthetized and their collars removed, wounds cleaned and debrided, topical antiseptic powder applied, and 70 cc of long acting penicillin administered intramuscularly. On January 21, 1988, 8 horses were anesthetized and collars were removed on 4 horses, readjusted on 2 horses, and no damage found on 2 horses. The same treatment was applied to the 4 horses which had the collars as the horses on 1/16/88.

Summary of injuries is as follows:

- 1 horse with necrosis of skin and subcutaneous tissue about 1 inch deep under the entire collar
- 1 horse with necrosis on top of neck about 1 1/2 inch deep because the radio transmitter had twisted to the top
- 6 horses with necrosis under the neck just caudal to the larynx—ranging from 1 to 2 inches deep

The necrosis on all of these horses was caused by pressure of tight collars. The damage was only to skin and subcutaneous tissues with various amounts of localized infection. No vital structures (i.e., trachea, arteries, or veins) were involved. White blood cell counts on the first 4 horses showed no signs of systemic infection. All horses were in good condition.

One of the horses with no damage from the collar died about 1 hour after being darted. She had recovered from the anesthesia but because of a debilitated condition due to old age (≈30 years) and resulting poor teeth, she could not recover from the stress of the anesthesia.

None of the horses with pressure necrosis from the radio collars appeared to be in imminent danger of dying. As I have stated before, these horses showed no sign of systemic infection and were in good condition. However wounds caused by the tight collars appeared to be quite painful and if the collars were not removed or adjusted more serious damage and the possibility of death could have resulted sometime in the future. There are certain factors that vary with time (i.e., weight gain or loss) that dictate animals in the wild with tracking collars must be monitored on a regular basis to deal with problems that arise before they become serious. Wild horses having problems with tight collars must be identified and treated. They should be observed at regular intervals at least 4 times a year.

Gerald R. Peck, D.V.M.